Development Of The Bragg-Peak Position Monitoring System In Particle Therapy By Using e+ e- Pair Production Events

Shota KIMURA[1], Yusaku EMOTO[1], Kento FUJIHARA[1], Hiroshi ITO[1], Hideyuki KAWAI[1], Atsushi KOBAYASHI[1], Hiroyoshi MATSUNAGA[2], Takahiro MIZUNO[1], Taichi NAKAMURA[1], Taiki TANAKA[2], and Takamichi YUZAWA[2]

[1]Graduate School of Science and Engineering, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba, 263-8522, Japan
[2]Faculty of Science, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba, 263-8522, Japan

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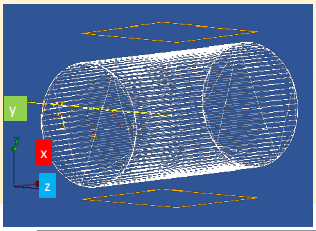
Introduction

In particle therapy, it is important to monitor the Bragg-peak position. To monitor the Bragg-peak position, positron emission tomography detectors [1], or Compton cameras [2] have been studied.

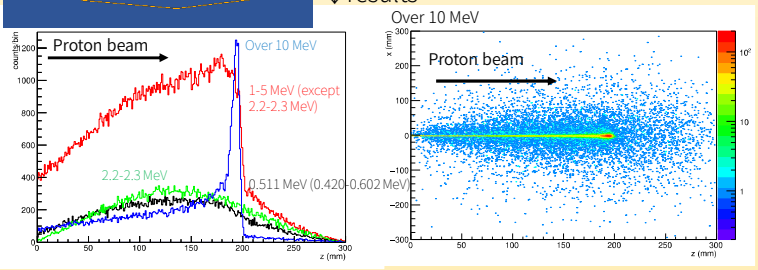
Simulation of secondary generated gamma rays on the proton beam therapy



←geometry

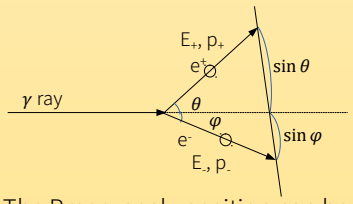
- Gamma rays whose energy is 10 MeV or more are intensively generated at the Bragg-peak position.

↓results



Method

- Most of the reaction of gamma rays which energy is 10 MeV or more are pair production [3].
- The momentum direction of the gamma ray can be determined by measuring passing points and energy of e^+ and e^- generated by pair production.

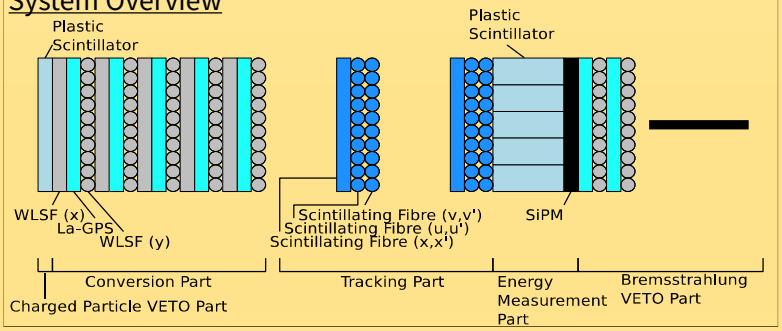


$$p_+ \sin\theta = p_- \sin\varphi$$

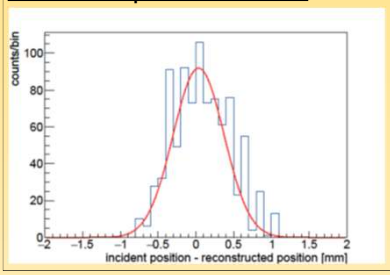
$$\sin\theta : \sin\varphi = p_- : p_+ = \sqrt{{E_-}^2 - {m_e}^2} : \sqrt{{E_+}^2 - {m_e}^2} \rightarrow E_- : E_+$$

- The Bragg-peak position can be determined by obtaining the intersection of the trajectory of the gamma ray and the trajectory of the particle beam.

System Overview

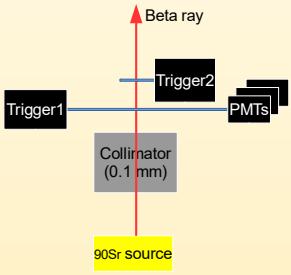


Former experiment data

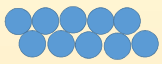


- Position resolution of La-GPS and WLSF sheet (conversion part) was measured as **1.067 ± 0.0017** mm in sigma.
- Details are shown in ANIMMA 2017 poster.

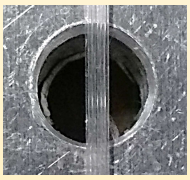
Experiment



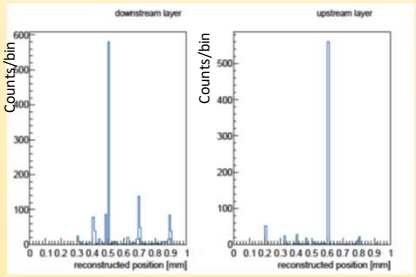
- Checking feasibility of scintillating fibre sheet.
- Using ϕ0.2 mm fibres.
- 2 layers are multi-stacked in trefoil formation.



- Beta rays are collimated by 1 cm-thickness brass.



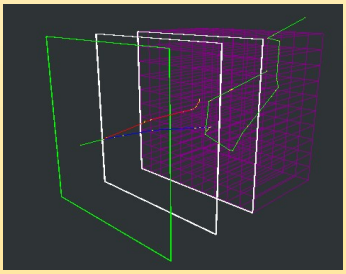
Result of experiment



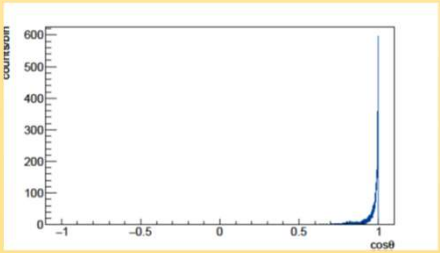
- One fibre emits lights at each event on a upstream layer.
- On a downstream layer, beam are spread than on a upstream layer.

Simulation

- Shot 20 MeV gamma rays
- No VETO counters
- 10 cm distance between layers



Result of Simulation



- θ: angles between incident gamma ray and reconstructed path
- Position resolution of conversion is considered.

•$\cos\theta$ has a peak at $\cos\theta = 1$

Discussions and Conclusions

- **Angle resolution of this system was simulated as 0.0848 rad in FWHM.**
- **This may be better when consider VETO counter, energy loss of e+ and e-.**

Acknowledgements

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References

[1] T. Nishio, T. Ogino, K. Nomura, and H. Uchida, "Dose-volume delivery guided proton therapy using beam on-line pet system," Medical physics, vol. 33, no. 11, pp. 4190–4197, 2006.
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[3] M. Berger, J. Hubbell, S. Seltzer, J. Chang, J. Coursey, R. Sukumar, D. Zucker, and K. Olsen, "Xcom: Photon cross sections Database," https://www.nist.gov/pml/xcom-photon-cross-sections-database.